Q1.

3 (a)  (i) simple/discrete covalent/molecular [1]
   (ii) giant/macro covalent/molecular (NOT atomic) [1]
   (iii) (giant) ionic [1]
   a general statement that strong attraction means high m.pt. and weak means low [1]

(b)  (i) \[ \text{CO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} \]
   or \[ \text{CO}_2 + \text{NaOH} \rightarrow \text{NaHCO}_3 \] (this mark is negated if candidate states that SiO$_2$ dissolves/reacts) [1]
   \[ \text{SnO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SnO}_3 + \text{H}_2\text{O} \]
   or \[ \text{SnO}_2 + 2\text{NaOH} + \text{H}_2\text{O} \rightarrow \text{Na}_2\text{Sn(OH)}_4 \text{etc} \] [1]
   (if neither of the above marks can be awarded, allow CO$_2$ and SnO$_2$ dissolve/react but SiO$_2$ does not, for [1])
   (ii) CO$_2$ and SiO$_2$ - no reaction [1]
   \[ \text{SnO}_2 + 4\text{HCl} \rightarrow \text{SnCl}_4 \text{ (or Sn}^{4+} + 4\text{Cl}^-) + 2\text{H}_2\text{O} \] [1]

(c) \[ \text{PbO}_2 + 4\text{HCl} \rightarrow \text{PbCl}_2 + 2\text{H}_2\text{O} + \text{Cl}_2 \] [1]
   \[ E_{\text{cell}} = 1.47 - 1.36 \]
   \[ = 0.11 \text{ (V) [for 1 M HCl]} \] [1]
   or
   \[ \text{Pb}^{4+} + 2\text{Cl}^- \rightarrow \text{Pb}^{2+} + \text{Cl}_2 \] [1]
   \[ E_{\text{cell}} = 1.69 - 1.36 \]
   \[ = 0.33 \text{ (V) [for 1 M HCl]} \] [1]

Q2.

1
2 (a) covalent (giant or macro) negates, as also does any reference to ionic bonding
(simple molecular is not enough – look for covalent)
tetrahedral

(b) (i) plotting (allow ±1°)
138 – 151°C (stated in numbers, or read from the graph)
(ii) (b. pt. increases due to) larger intermolecular / van der Waals / induced dipole
(NOT permanent dipole) / attractions
due to the larger no. of electrons or more shells of electrons (in MX₄)

(c) (i) Si has empty low-lying orbitals or empty d-orbitals (C does not)
(ii) \( \text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl} \)
[or \( \text{SiCl}_4 + 4\text{H}_2\text{O} \rightarrow \text{Si(OH)}_4 + 4\text{HCl} \) etc.]
(iii) (yes), because Ge also has empty (low lying d-) orbitals

(d) (i) \( \text{SiCl}_4 + 2\text{Zn} \rightarrow \text{Si} + 2\text{ZnCl}_2 \) [NOT ionic equation]
(ii) mass = 250 x 2 x 65.4/28.1
\[ = 1164 \text{ (g) (actually 1163.7 – but allow 1160)} \]

*allow e.c.f from the stoichiometry of the candidate’s equation e.g. allow 582g for
[2] marks if the equation shows the stoichiometry to be 1:1. But if 582g is obtained
because the candidate forgot to apply the stoichiometry as given in the equation,
award only [1] mark.*

correct answer = [2], with – [1] for one error. OR marks as follows:
use of 2:1 ration \[ [1] \]
correct use of A₁ data for Si and Zn \[ [1] \]

Total = [12]
Q4. 

3 (a) (i) \(2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2\) 
\(2\text{PbO}_2 \rightarrow 2\text{PbO} + \text{O}_2\) 
\(\downarrow\) (or \(x \frac{1}{2}\)) \[1\] 

(ii) +4 state becomes less stable down the group 
or +2 state becomes more stable down the group \[2\] 

(b) (i) \(\text{Pb}^{2+}: \text{Pb}^{4+} = 2:1\) \[1\] 

(ii) \(\text{Pb}_2\text{O}_4 \rightarrow 3\text{PbO} + \frac{1}{2}\text{O}_2\) \[1\] 

(iii) \(\text{Pb}_2\text{O}_4 + 4\text{HNO}_3 \rightarrow 2\text{Pb(NO}_3)_2 + \text{PbO}_2 + 2\text{H}_2\text{O}\) \[1\] 

(iv) \(\text{PbO}/\text{Pb}^{(II)}\) is more basic than \(\text{PbO}^+/\text{Pb}^{(IV)}\) 
as \(\text{PbO}_2\) does not react / form a salt with \(\text{HNO}_3\) 
or \(\text{PbO}\) does react etc. \[5\] 

(c) \(\text{SnO} + 2\text{NaOH} \rightarrow \text{Na}_2\text{SnO}_2 + \text{H}_2\text{O}\) 
(NOT \(\text{SnO}_2\) or \(\text{PbO}\)) \[1\] 
\(\text{(or Na}_2\text{Sn(OH)}_4\text{ etc.)}\) \[1\] 

[Total: 8] 

Q5. 

3 (a) tetrahedral diagram (either dashed+wedge, or similar representation) 
angles (all) 109° – 110° 
(award [0] for part (a) if an angle of 90° or 180° is mentioned) \[1\] 

(b) volatility decreases or boiling points increase 
(allow b.p.t. \(\text{CCl}_4 > \text{SiCl}_4\) but b.p.t. increases thereafter) 
due to greater van der Waals/intermolecular forces or due to more electrons 
(mention of “Ions” negates this mark) \[2\] 

(c) (i) \(\text{Pb}^{4+}/\text{Pb}^{2+}: E^\circ = +1.69V, \text{Sn}^{4+}/\text{Sn}^{2+}: E^\circ = +0.15V,\) 
a valid comment about relative redox power or stability, e.g.: 
(hence) \(\text{Sn}^{2+}\) easily oxidised or \(\text{Sn}^{4+}\) is more stable than \(\text{Sn}^{2+}\) 
or \(\text{Pb}^{4+}\) is easily reduced or \(\text{Pb}^{2+}\) is more stable than \(\text{Pb}^{4+}\) 
or +2 oxidation state more stable down the group \[1\] 

(ii) \(\text{Sn}^{2+} + \text{I}_2 \rightarrow \text{Sn}^{4+} + 2\text{I}^-\) \[1\] 
\(\text{Pb}^{4+} + \text{SO}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + \text{SO}_4^{2-} + \text{Pb}^{2+}\) 
(N.B. no marks in (b) for \(E^\circ\) values) \[4\] 

(d) (i) for \(\text{Si}: \Delta H = 244 - 2(359) = -474\) (kJ mol\(^{-1}\)) \[1\] 
for \(\text{Sn}: \Delta H = 244 - 2(315) = -386\) (kJ mol\(^{-1}\)) 
(allow [1] out of [2] salvage mark for 474 & 386; 962 & 874; or -962 & -874) \[1\] 

(ii) Yes: the +4 state becomes increasingly stable – the \(\Delta H\) is less exothermic 
(mark is for relating \(\Delta H\)s to stability: allow ecf from (d(i)) and also from (c(i))) \[3\] 

[Total: 11]
(a) \( \text{PbO}_2 \) decomposed into PbO (and \( \text{O}_2 \)). (SnO\(_2\) is stable)  

(b) (i) \( \text{PbCl}_4 \) dissociates into \( \text{Cl}_2 \) and \( \text{PbCl}_2 \) (white solid)  
\[ \text{or PbCl}_4 \rightarrow \text{PbCl}_2 + \text{Cl}_2 \]  
\[ \text{or in words} \]

\[ \text{Cl}_2 + 2\text{KI} \rightarrow 2\text{KCl} + \text{I}_2 \]  

\[ \text{E}^0(\text{Cl}_2/\text{Cl}^-) \text{ is more positive than E}^0(\text{I}_2/\text{I}^-) \]  

(ii) \( \text{SnCl}_4 \) is more stable than \( \text{PbCl}_4 \) / answers using \( \text{E}^0 \) accepted  

(c) (i) \[ \begin{array}{c} \text{Cl:C:Cl} \\ \text{or} \\ \text{Cl=C-Cl} \end{array} \]  

bent or non-linear or angle = 100–140\(^\circ\)  

(ii) \( \text{CCl}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 2\text{HCl} \)

Total: 8

Q6.

3 (a) \( \text{SiF}_4 \) is symmetrical or tetrahedral or bonds are at 109\(^\circ\) or has no lone pair or 4 electron pairs shared equally or all Si-F dipoles cancel out, or \( \text{SF}_4 \) has a lone pair (on S).

(b)  

<table>
<thead>
<tr>
<th>compound</th>
<th>molecule has an overall dipole</th>
<th>molecule does not have an overall dipole</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{BCl}_3 )</td>
<td>( \checkmark )</td>
<td>( \checkmark )</td>
</tr>
<tr>
<td>( \text{PCl}_3 )</td>
<td>( \checkmark )</td>
<td>( \checkmark )</td>
</tr>
<tr>
<td>( \text{CCl}_4 )</td>
<td>( \checkmark )</td>
<td>( \checkmark )</td>
</tr>
<tr>
<td>( \text{SF}_4 )</td>
<td>( \checkmark )</td>
<td>( \checkmark )</td>
</tr>
</tbody>
</table>

mark row-by-row.

(c) (i) \text{Si and B have empty / available / low-lying orbitals or C does not have available orbitals (allow "B is electron deficient" but not mention or implication of d-orbital on B)}

(ii) \( \text{BCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{H}_3\text{BO}_3 + 3\text{HCl} \) or \( 2\text{BCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{B}_2\text{O}_3 + 6\text{HCl} \)

\( \text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}\text{ etc., e.g. } \rightarrow \text{Si(OH)}_4, \text{H}_2\text{SiO}_3 \)
Q7.

\[\text{(d) (i) } \text{Si}_2\text{Cl}_6\text{O}_2 \text{ (this has } M = 84 + 280 + 32 = 396 \text{) or } \text{Si}_4\text{Cl}_4\text{O}_9 \text{ or } \text{Si}_8\text{Cl}_8\text{O}_2 \quad (1)\]

\[\text{(ii) mass number} \quad \text{structure} \]
\begin{tabular}{|c|c|}
\hline
133 & $\text{Cl}_2\text{Si}$ \\
247 & $\text{Cl}_2\text{Si-O-SiCl}_2$ \\
263 & $\text{Cl}_2\text{Si-O-SiCl}_2\text{-O}$ \\
\hline
\end{tabular} \quad (3)

(if correct structures are not given for last 2 rows, you can award (1) mark for two correct molecular formulae: either $\text{Si}_2\text{Cl}_3\text{O} + \text{Si}_2\text{Cl}_6\text{O}_2$ or $\text{Si}_4\text{Cl}_4\text{O}_9 + \text{Si}_6\text{Cl}_6\text{O}_6$ or $\text{Si}_7\text{Cl}_7\text{O}_7 + \text{Si}_7\text{Cl}_7\text{O}_7$)

\[\text{(iii)} \quad \text{allow ecf on the structure drawn in the third row of the table in (ii)} \quad \text{but any credited structure must show correct valencies for Si, Cl and O.} \quad \text{(1) [5]} \]

[Total: 11]

Q7.

\[2 \quad \text{(a) (i)} \]

\[\text{melting point} \quad \text{electrical conductivity} \]
\begin{tabular}{|c|c|c|c|}
\hline
m. pt. & high & med. & low \\
C & & & \\
Si & & & \\
Ge & & & \\
Sn & & & \\
Pb & & & \\
\hline
\end{tabular} \quad \begin{tabular}{|c|c|c|c|}
\hline
m. pt. & high & med. & low \\
C & & & \\
Si & & & \\
Ge & & & \\
Sn & & & \\
Pb & & & \\
\hline
\end{tabular} \quad [2] + [2]

\[\text{(ii) m. pt. trend: (from) giant/macro molecular/covalent to metallic bonding} \quad \text{(1)} \]
\[\text{(or implied from at least two specific examples, e.g. diamond and tin)} \quad \text{(mention of simple covalent anywhere negates this mark)} \quad [1] \]
\[\text{conductivity trend: increasing delocalisation of electrons (down the group)} \quad [1] \]
\[\text{or } e^- \text{ are more free-moving} \quad [6] \]
\[\text{(or implied from at least two examples, e.g. Si is semiconductor, lead has delocalised } e^- \text{)} \]
Q8.

(a) (i) 4 volatilities decrease down the group

due to greater van der Waals (VDW) forces (intermolecular is not sufficient)

due to larger no of electrons

(ii) CCl₄ does not react with water

CCl₄ unreactive due to no d-orbitals

GeCl₄ and PbCl₄ hydrolyse/react

MCl₄ + 2H₂O → MO₂ + 4HCl (M = Ge or Pb)

(b) (i) B is PbSO₄ and C is PbCl₄

(ii) SnO₂ + 2H₂SO₄ → Sn(SO₄)₂ + 2H₂O

PbO₂ + H₂SO₄ → PbSO₄ + H₂O + ½ O₂

PbO₂ + 6HCl → H₂PbCl₆ + 2H₂O

H₂PbCl₆ → PbCl₄ + 2HCl + Cl₂

[Total: 11 max 10]
Q9.

3 (a) (i) diag:

- C, Si, Ge: giant/macro covalent/molecular/atomic weaker/longer bonds in Si or Ge than C
- Sn or Pb or "the last two": metallic bonding

If [2] cannot be awarded, look at the following alternative marking schemes:

**either** split the curve into two parts: C to Ge and Ge to Pb. Give [1] for each part if it's correct
**or** award [1] for a general downward trend in the whole curve

(b) (i) no reaction/hydrolysis or insoluble or immiscible
(ii) gives (HCl) fumes/gas or ppt/white solid/gel (of SiO₂)
(iii) SiCl₄ + 2H₂O → SiO₂ + 4HCl [allow balanced equations giving H₂SiO₃ or Si(OH)₄, but not partial hydrolysis to SiOCl₂ etc]
(iv) Si has (available) d-orbitals (so attack by nucleophiles is easier)

Total: 9 max 8

Q10.
3 (a) (i) melting point: graph showing (Si (+ Ge): medium) and C: higher than Si/Ge
Sn + Pb: lower than Si/Ge
conductivity: graph showing (Si (+ Ge): medium) and C: lower (or higher) than Si/Ge
Sn + Pb: higher than Si/Ge
[for your information, the actual figures are shown below]

(ii) Sn, Pb (and C(graphite)) have delocalised electrons/metabolic bonds
Si, Ge (and C(diamond)) have localised electrons/covalent bonds
[for [2] marks carbon has to be mentioned once, and the allotrope mentioned must fit in with the conductivity shown]

(b) (i) e.g. CO burns to give CO₂ \[2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2\]
or CO reduces Fe₂O₃ \[3\text{CO} + \text{Fe}_2\text{O}_3 \rightarrow 3\text{CO}_2 + 2\text{Fe}\]

(ii) e.g. PbO₂ decomposes on heating \[2\text{PbO}_2 \rightarrow 2\text{PbO} + \text{O}_2\]
two valid examples
two balanced equations
[1] + [1]
two valid and balanced equations warrants [3] marks

(c) use: pottery/china/porcelain etc + property: hardness, high melting point, insulator etc.
(any one use + one relevant property)

(d) (i) amphoteric

(ii) e.g. \(\text{SnO} + 2\text{HCl} \rightarrow \text{SnCl}_2 + \text{H}_2\text{O}\)

e.g. \(\text{SnO} + 2\text{NaOH} \rightarrow \text{Na}_2\text{SnO}_2 + \text{H}_2\text{O}\)

(total: 13)

(Actual figures for (a) (i):)

<table>
<thead>
<tr>
<th>element</th>
<th>m.pt./°C</th>
<th>conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl(graph)</td>
<td>3652</td>
<td>(2 \times 10^7)</td>
</tr>
<tr>
<td>Cl(dia)</td>
<td>3550</td>
<td>(1 \times 10^{10})</td>
</tr>
<tr>
<td>Si</td>
<td>1410</td>
<td>(2 \times 10^6)</td>
</tr>
<tr>
<td>Ge</td>
<td>937</td>
<td>(2 \times 10^6)</td>
</tr>
<tr>
<td>Sn</td>
<td>232</td>
<td>(9 \times 10^6)</td>
</tr>
<tr>
<td>Pb</td>
<td>328</td>
<td>(5 \times 10^6)</td>
</tr>
</tbody>
</table>
Q12.

1. (a) Boiling points increase down the group (because of...)
   larger van der Waals/intermolecular attractions or bigger induced dipoles
   due to more electrons per molecule

(b) tetrahedral - clear from diagram
   angles = 109°-110°

(c) (i) four bonded pairs + 2 lone pairs around Xe
   three lone pairs on at least one F atom
   (ii) square planar (can be read into very clear diagram in (i))
   angles = 90°

(d) CCl₄ does not react or SiCl₄ does (or read into an equation)
   due to presence of available/low-lying/d-orbitals on Si
   SiCl₄ + 2H₂O → SiO₂ + 4HCl
   (or SiCl₄ + 4H₂O → Si(OH)₄ + 4HCl etc: also allow partial hydrolysis)

(e) PbCl₂ + 8Na + 4C₂H₅Cl → Pb(C₂H₅)₄ + 8NaCl
   Pb(C₂H₅)₄ = 207 + 4x29 = 323
   323g needs 8 x 23 = 184g Na
   .1000g needs 1000 x 184/323 = 569 or 570g
   ecf from eqn
   (correct ans = (2) marks)

(alternative method:
1.0kg of Pb(C₂H₅)₄ is 3.096 moles
:: we need 8 x 3.096 = 24.77 moles of Na, which is 569 or 570g)

[Total: 15]

4. (a) CCl₄ is unreactive. (The rest react with increasing vigour)
   no d-orbitals or available/low-lying empty orbitals in carbon or unable to expand octet
   e.g. SiCl₄ + 2H₂O → SiO₂ + 4HCl
   (or GeCl₄ etc)
   or Si(OH)₂Cl₂
   or Si(OH)₄
   (allow balanced equations for partial hydrolysis)

(b) (i) E(Cl-Cl) = 244 kJ mol⁻¹; 2 E(C-Cl) = 2 x 340 = 680 kJ mol⁻¹
   :: ΔH = -436 (kJ mol⁻¹)

(ii) ΔH = 359 - 329 = +30 (kJ mol⁻¹)

(iii) since reaction (ii) is endothermic, the +4 oxidation state is less stable
     or the +2 oxidation state is more stable (down the group)

[Total: 6]
Q13.

4 (a) (i) \( \text{SnO}_2 \) Can be read into equation (1)
\[
2\text{NaOH} + \text{SnO}_2 \rightarrow \text{Na}_2\text{SnO}_3 + \text{H}_2\text{O} \quad (1)
\]

(ii) \( \text{PbO} \) Can be read into equation (1)
\[
\text{PbO} + 2\text{HCl} \rightarrow \text{PbCl}_2 + \text{H}_2\text{O} \quad (1)
\]

(b) moles of oxygen = \( 9.3/16 = 0.581 \text{ mol} \)
moles of lead = \( 90.7/207 = 0.438 \text{ mol (both 3.s.f.)} \) (1)
so formula is \( \text{Pb}_2\text{O}_4 \) (1)

(c) (i) \( K_{sp} = [\text{Pb}^{2+}][\text{Cl}^-]^2 \) (1) units = \( \text{mol}^3 \text{ dm}^{-9} \) (1)

(ii) if \( [\text{Pb}^{2+}] = x \), \( K_{sp} = 4x^3 \), so \( x = \sqrt[3]{K_{sp}/4} \)
\[
[\text{Pb}^{2+}] = \sqrt[3]{(2 \times 10^{-5}/4)} = 1.71 \times 10^{-2} \text{ mol dm}^{-3} \quad (1)
\]

(iii) \( [\text{Pb}^{2+}] = 2 \times 10^{-5}/(0.5)^2 = 8.0 \times 10^{-6} \text{ mol dm}^{-3} \) (1)

(iv) common ion effect, or increased [Cl\(^-\)] forces solubility equilibrium over to the left (1)

[Max 4]

[Total: 10]

Q14.

8 (a) (i) diagram to show tetrahedral arrangement (3D or bond angle marked) (1)

(ii) 4 covalent bonds/bond pairs (with Cl\(^-\)) **only or no lone pairs**. (1)

(b) (i) steamy/white fumes/gas or heat evolved (1)
(fumes are) \( \text{HCl} \) (from hydrolysis of Sn-Cl bonds) or exothermic reaction/bond breaking (1)
can award second mark for \( \text{HCl} \) in eqn.

(ii) \( \text{SnCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SnO}_2 + 4\text{HCl} \) etc. (allow partial hydrolysis and with OH\(^-\)) (1)

[Total: 5]
Q16.

2  (a)  (i)  Si-Si bonds are weaker (than C-C bonds)  [1]

(ii) metallic (Sn) is weaker than (giant) covalent (Ge)  [1]

(b)  (i)  \( \text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl} \)

   \( \text{or} \ \text{SiCl}_4 + 4\text{H}_2\text{O} \rightarrow \text{Si(OH)}_4 + 4\text{HCl} \)

   \( \text{or} \ \text{SiCl}_4 + 3\text{H}_2\text{O} \rightarrow \text{H}_2\text{SiO}_3 + 4\text{HCl} \)

   (partial hydrolysis is not sufficient e.g. to \( \text{SiCl}_4\text{OH} + \text{HCl} \))  [1]

(ii)  \( \text{PbCl}_4 \rightarrow \text{PbCl}_2 + \text{Cl}_2 \)

(iii)  \( \text{SnCl}_4 + 2\text{FeCl}_3 \rightarrow \text{SnCl}_2 + 2\text{FeCl}_2 \)

(iv)  \( \text{SnO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SnO}_3 + \text{H}_2\text{O} \)

   \( \text{or} \ \text{SnO}_2 + 2\text{NaOH} + 2\text{H}_2\text{O} \rightarrow \text{Na}_2\text{Sn(OH)}_6 \)

   \( \text{or} \ \text{ionic equation} \ \text{SnO}_2 + 2\text{OH}^- \rightarrow \text{SnO}_2{}^{2-} + \text{H}_2\text{O} \)  [1]

[Total: 6]

4  (a)  (i)  Carbon (graphite) has delocalised electrons whereas silicon's electrons are localised.  [1]

(ii)  Tin has metallic structure or delocalised/mobile electrons whereas germanium has localised electrons or giant covalent structure  [2]

(b)  (i)  \( 2\text{PbO}_2 \rightarrow 2\text{PbO} + \text{O}_2 \)  [1]

(ii)  \( \text{PbO}_2 + 4\text{HCl} \rightarrow \text{PbCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O} \)  [1]

(iii)  \( \text{SnO} + 2\text{NaOH} \rightarrow \text{Na}_2\text{SnO}_2 + \text{H}_2\text{O} \)  [1]

(iv)  \( \text{GeCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{GeO}_2 + 4\text{HCl} \)  [4]

[Total: 6]